Basics of Magnetic & Eddy Current Thickness Measurements

By Bob Wells

Many destructive and nondestructive coating thickness measuring instruments are available for use in the plating industry that can help to minimize plating failures and control costs. These instruments employ a variety of methodologies and techniques.

Two of the most common nondestructive coating measurement methods, the magnetic and eddy-current principles, have been incorporated into portable, hand-held devices. An overview of some of the more common types of instruments and techniques is as follows.

Magnetic Principle

The magnetic technique is used for nondestructive measurement of the thickness of nonmagnetic plating or coatings on ferrous substrates. Plating applications that can be measured by conventional magnetic gages include chromium, zinc, copper, cadmium, “galvalume,” titanium and high-phosphorus (>8%) electroless nickel on ferrous metals such as steel. Of course, any nonmagnetic material such as paint and enamel applied to steel can also be measured by these gages.

Gages that operate on the magnetic technique use one of two principles of operation: magnetic pull-off (mechanical) or magnetic/electromagnetic induction (electronic).

Magnetic Pull-Off Gages

Magnetic pull-off gages consist of a permanent magnet, a calibrated spring and a graduated scale. The attractive force between the permanent magnet and the steel pulls the magnet toward the steel. The magnitude of this attractive force is related to the separation distance (gap) between the magnet and the steel.

Pull-off force is defined as the force required to pull the magnet from the plated steel. This force must be equal to and opposite that of the attractive force and is directly, but non-linearly related to the plating or coating thickness. Thickness is determined by this pull-off force. The weaker the applied force necessary to release the magnet from the surface, the thicker the plating or coating.

This type of gage is rugged, simple, inexpensive, portable, and usually factory-calibrated. It is capable of accurately measuring the thickness of plating in the range of 0–4 mil (0–100 µm). Pull-off gages are also used to measure thicker coatings, such as hard chromium, paint and enamel, which often require use of an instrument with greater range (*i.e.*, 0–80 mil or 0–2000 µm).

Pen-type pull-off gages (Fig. 1) consist of a magnet attached directly or indirectly to a helical spring. The spring acts perpendicularly to the magnetic surface and pulls the magnet from the surface. Most of these instruments have large magnets designed to work in only one or two positions. Typical accuracy is ±15 percent or greater. More accurate versions that use a very small, precise magnet for measuring plating on small, hot, or hard-to-reach surfaces are also available. They have a triple indicator to compensate for gravity. This allows them to be used in downward, upward, and horizontal positions. The tolerance or accuracy of this type is ±10 percent.

Fig. 1—Pen-type pull-off gage.

Fig. 2—Roll-back dial gage.

Roll-back Dial Gages

Roll-back dial gages are the most common form of magnetic pull-off gage. A magnet is mounted to one end of a pivoting balance arm. This assembly is connected to a calibrated spring. Rotation of the external dial causes the spring to increase the force on the magnet and pulls the magnet from the plated surface. These gages are durable, easy to use, hold the reading on the dial, and have a balanced arm that allows it to be used in any position, independent of gravity (Fig. 2). The typical accuracy is ±5 percent. Standard methods have been developed for additional guidelines when using these types of instruments. Refer to ASTM Test Method D1186A.

Fig. 3—Eddy current gage with liquid crystal display.

Eddy-Current Principle

The eddy-current technique is a very common method of measuring nonconductive coatings on nonferrous metals. Applications that can be measured by the conventional eddy-current gage include powder coating on copper, zinc and aluminum; paint on copper, zinc and aluminum; and anodizing on aluminum.

Eddy-current measurement is based on the principles of electromagnetic induction. A coil of fine wire conducting a high-frequency alternating current (>1 MHz) is used to set up an alternating magnetic field at the surface of the instrument's probe. When the probe is brought near a conductive surface, the alternating magnetic field will set up eddy currents on the surface. The eddy currents create their own opposing electromagnetic fields that are detected by the probe. The magnitudes of the eddy currents are related to substrate characteristics and the distance (coating thickness) from the exciting field.

Instruments that employ the eddy-current technique typically use a constant pressure probe and display results on a liquid crystal display (Fig. 3). Features of some of the more advanced models include an "average zero" feature, statistical capabilities, and memory (data storage) for downloading to a serial printer or computer. Manufacturer's instructions should be carefully followed for the most accurate results. Accuracy of these gages is typically ±1 to 3 percent.

Standard methods for the application and performance of this test are available in ASTM B 244 and ASTM D 1400.

Application Variables

Coating and plating thickness measurements are sensitive to surface roughness, substrate curvature, alloy content and, in the case of some instruments, substrate thickness. Advanced measuring instruments incorporate features that can help to overcome these variables by compensating the instrument for these conditions. Manufacturer's instructions should be carefully followed to ensure accurate results. P&SF

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